PB-240 202

CASS LAKE, BELTRAMI AND CASS COUNTIES, MINNESOTA

Pacific Northwest Environmental
Research Laboratory

Prepared for:

National Environmental Research Center
Minnesota Pollution Control Agency
Minnesota National Guard

November 1974

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
CASS LAKE
BELTRAMI AND CASS COUNTIES
MINNESOTA
EPA REGION V
WORKING PAPER No. 92

WITH THE COOPERATION OF THE
MINNESOTA POLLUTION CONTROL AGENCY
AND THE
MINNESOTA NATIONAL GUARD
NOVEMBER, 1974

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

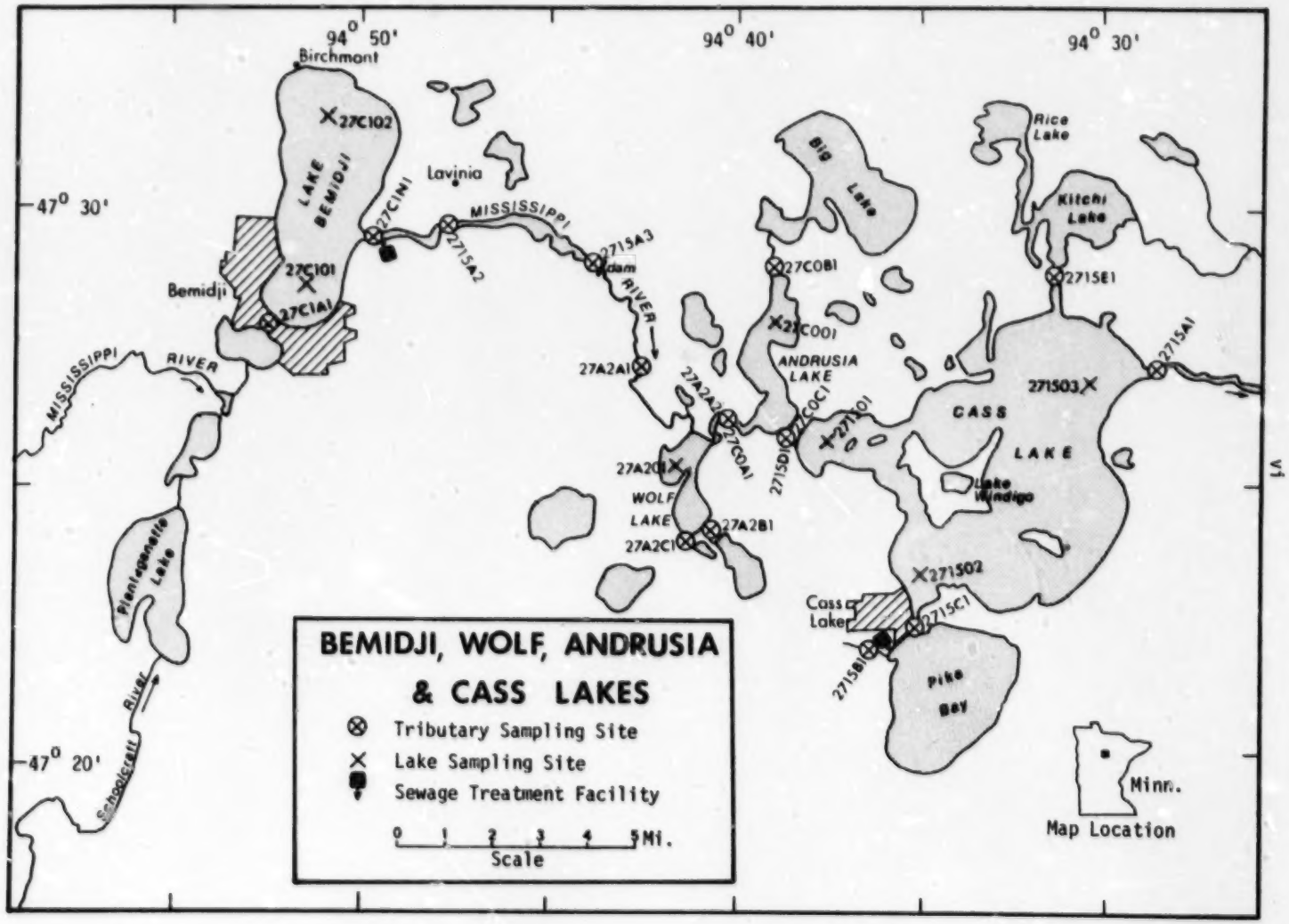
NATIONAL EUTROPHICATION SURVEY

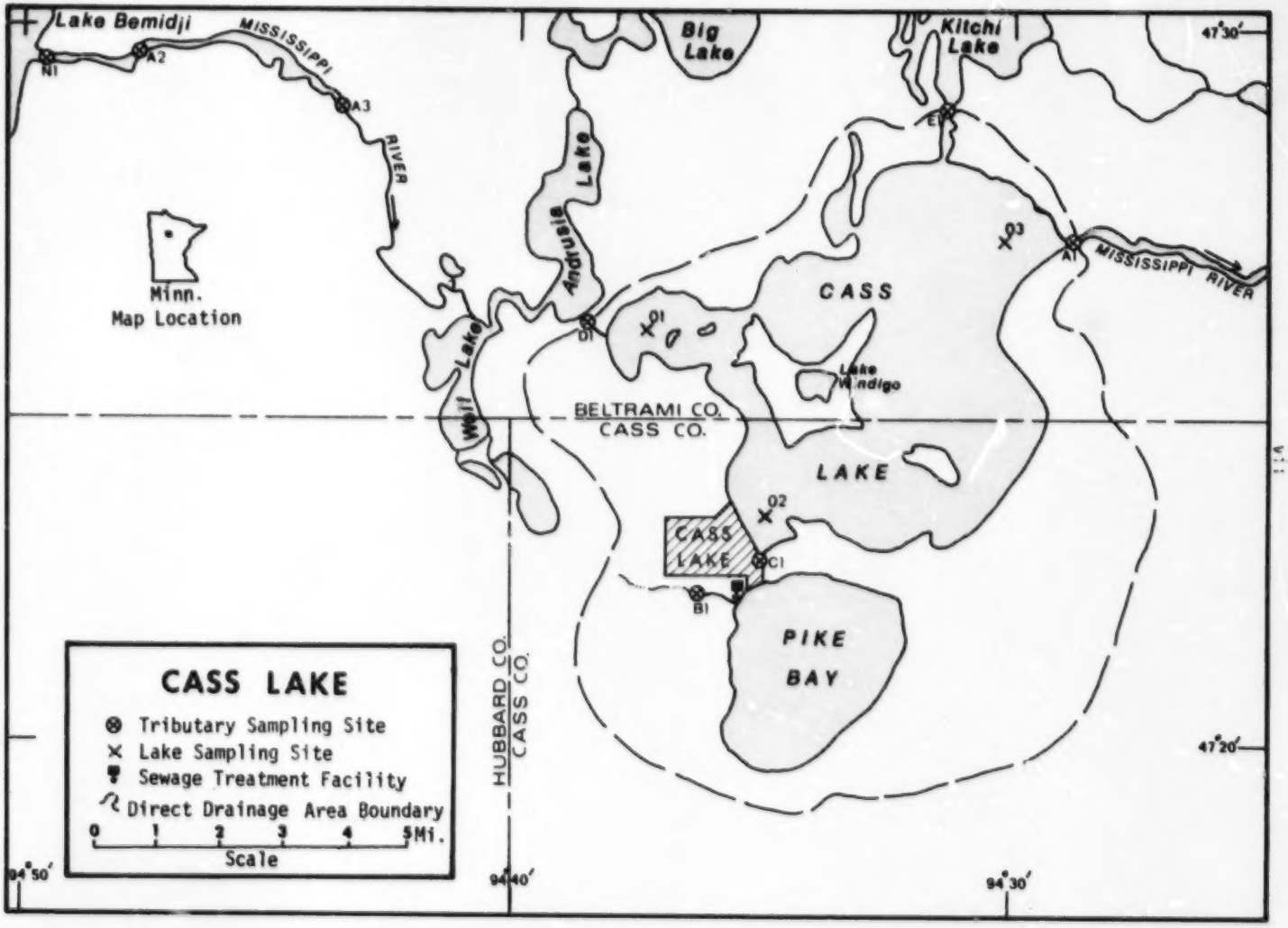
STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


94° 50'
94° 40'
94° 30'
47° 30'
47° 20'
Birchmont
LAKE BEMIDJI
27C102
27C101
27C1A1
Bemidji
27C1N1
Lavinia
MISSISSIPPI
27I5A2
27I5A3
dam
RIVER
MISSISSIPPI
RIVER
Big Lake
27C0B1
27C001
ANDRUSIA LAKE
27A2A1
27A2A2
27C0C1
27C0A1
27I501
27I5D1
27A2D1
WOLF LAKE
27A2B1
27A2C1
Rice Lake
Kitchi Lake
27I5E1
27I5A1
271503
CASS LAKE
Lake Windigo
271502
Cass Lake
27I5C1
27I5B1
Pike Bay
Pleasant Lake
Schoolcraft River
BEMIDJI, WOLF, ANDRUSIA & CASS LAKES
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0 1 2 3 4 5 Mi.
Scale
Minn.
Map Location


Lake Bemidji
MISSISSIPPI
RIVER
N1
A2
A3
Big Lake
Kitchi Lake
47°30'
E1
Minn.
Map Location
Andrusia Lake
Wilt Lake
D1
CASS
LAKE
Lake Windigo
A1
MISSISSIPPI RIVER
BELTRAMI CO.
CASS CO.
LAKE
CASS LAKE
C1
B1
PIKE BAY
HUBBARD CO.
CASS CO.
47°20'
94°50'
94°40'
94°30'
CASS LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Boundary
0 1 2 3 4 5Mi.
Scale

CASS LAKE

STORET NO. 2715

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that the main body of Cass Lake is mesotrophic. Reportedly, the only portion of the lake exhibiting nuisance conditions of any kind is Allen's Bay near the Lake Andrusia outlet channel (Lang, et al., 1969). Less than ½ acre of the lake was chemically treated for the control of rooted aquatic vegetation in 1971 (Bonnema and Johnson, 1972).

Of the 60 Minnesota lakes sampled in the fall when essentially all were well-mixed, only 6 exhibited better overall water quality based on the parameters measured during the Survey.

B. Rate-Limiting Nutrient:

Because of a loss of phosphorus in the sample, the algal assay results are not reliable.

Lake data indicate nitrogen limitation in October but phosphorus limitation in July and September of 1972.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Cass Lake received a total phosphorus loading at a rate less than that proposed by Vollenweider (in press) as dangerous but greater

than the permissible rate; i.e., a mesotrophic rate (see page 13). Of this load, it is estimated that the Bemidji STP contributed almost 34% (see "Report on Wolf Lake", Working Paper No. 136), and the Cass Lake STP contributed about 7%.

When the phosphorus removal facilities at Bemidji become operational, it is calculated that the total phosphorus load to Cass Lake will be reduced by about 28%. This will reduce the loading rate from the existing 3.1 lbs/acre/yr (0.35 g/m^2/yr) to about 2.3 lbs/acre/yr or 0.26 $g/m^2/yr$.

The new loading rate will be less than Vollenweider's permissible rate and should result in improvement of the trophic state of Cass Lake.

During the sampling year, it did not appear that the nutrients from the Cass Lake STP had a direct effect on Cass Lake; however, the receiving water--Pike Bay-- was not sampled. The discharge may be significant in the Bay.

2. Non-point sources (see page 13)--The phosphorus exports of the Cass Lake drainage were very similar to those of the drainages of the other lakes in this upper Mississippi River chain of lakes. The relatively low exports probably result from the near-headwaters location of the lakes as well as land-use practices in this largely-forested area of Minnesota.

In all, it is estimated that non-point sources contributed about 60% of the total phosphorus load reaching Cass Lake during the sampling year.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 15,596 acres.
2. Mean depth: 25 feet.
3. Maximum depth: 120 feet.
4. Volume: 389,900 acre/feet.
5. Mean hydraulic retention time: 313 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Mississippi River	732.0 mi^2	421.3 cfs
Pike Bay outlet	37.7 mi^2	20.0 cfs
Kitchi Lake outlet	302.0 mi^2	168.6 cfs
Minor tributaries & immediate drainage -	33.9 mi^2	17.2 cfs
Totals	1,105.6 mi^2	627.1 cfs

2. Outlet -

Mississippi River**	1,130.0 mi^2	627.1 cfs

C. Precipitation***:

1. Year of sampling: 26.7 inches.
2. Mean annual: 23.8 inches.

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† DNR lake survey map (no date), not including Pike Bay; mean depth by random-dot method.

* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.

** Outflow adjusted to equal sum of inflows; area includes that of the lake.

*** See Working Paper No. 1, "Survey Methods".

III. LAKE WATER QUALITY SUMMARY

Cass lake, one of a chain of upper Mississippi River lakes (see map, page vi), was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from two or more depths at each station (see map, page vii). During each visit a single depth-integrated (15 feet or near bottom to surface) sample was composited from the three stations for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was composited from the three stations for algal assays. Also each time, a depth-integrated sample was collected at each station for chlorophyll a analysis. The maximum depths sampled were 41 feet at station 1, 15 feet at station 2, and 21 feet at station 3.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake was essentially well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

FALL VALUES

(10/21/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	5.2	5.9	5.8	6.6
Dissolved oxygen (mg/l)	9.8	10.6	10.8	11.0
Conductivity (μmhos)	280	287	288	298
pH (units)	8.2	8.3	8.3	8.4
Alkalinity (mg/l)	135	139	140	142
Total P (mg/l)	0.012	0.022	0.023	0.031
Dissolved P (mg/l)	0.006	0.011	0.011	0.016
NO_2 + NO_3 (mg/l)	0.010	0.029	0.025	0.050
Ammonia (mg/l)	0.030	0.048	0.045	0.070

ALL VALUES

Secchi disc (inches)	42	74	68	123

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/11/72	1. Dinobryon	593
	2. Anabaena	441
	3. Cyclotella	116
	4. Synedra	87
	5. Microcystis	80
	Other genera	333
	Total	1,650
09/07/72	1. Microcystis	2,495
	2. Anabaena	452
	3. Dinobryon	434
	4. Chroococcus	380
	5. Flagellates	163
	Other genera	922
	Total	4,846
10/21/72	1. Fragilaria	2,415
	2. Dinobryon	1,849
	3. Flagellates	1,358
	4. Scenedesmus	1,358
	5. Melosira	1,019
	Other genera	3,284
	Total	11,283

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
07/11/72	01	13.4
	02	7.0
	03	3.2
09/07/72	01	6.6
	02	5.0
	03	4.6
10/21/72	01	16.4
	02	15.9
	03	6.4

C. Limiting Nutrient Study:

There was a significant loss of about 54% of the dissolved phosphorus in the assay sample between the time of collection and the beginning of the assay. Had this loss not occurred, the expected control yield would have been about 3 mg/l dry weight.

The lake data indicate nitrogen limitation in October (N/P ratio = 7/1) but phosphorus limitation in July (N/P ratio = 19/1) and in September (N/P ratio = 28/1).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, from October, 1972, through September, 1973, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vii), except for the high runoff month of April, when two samples were collected, and the colder months when samples were not collected at several sites because of ice cover and low flows.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the mean concentrations in the unnamed tributary to Pike Bay at station B-1 and the mean ZZ flow.

The operator of the Village of Cass Lake wastewater treatment plant did not provide sufficient flow data to permit calculation of nutrient loads, and nutrient loads from that source were estimated at 2.5 lbs P and 7.5 lbs N/capita/year. In this report, these loads were assumed to have reached Cass Lake.

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* See Working Paper No. 1.

The Bemidji wastewater treatment plant is an indirect source of nutrients to Cass Lake. During the sampling year, Wolf Lake retained 12% of the total phosphorus and none of the inorganic nitrogen load†, and Lake Andrusia retained about 37% of the total phosphorus load estimated to have been received from the Bemidji STP and about 12% of the inorganic nitrogen††. Therefore, in the following tables, the loads attributed to the indirect point source (Bemidji STP) were estimated on the basis of retentions in Wolf and Andrusia lakes. The loads attributed to the Cass Lake inlet at station 2715D-1 are those measured minus the indirect Bemidji STP loads.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Cass Lake	1,317*	Imhoff	0.132**	Pike Bay
Bemidji***	11,400	trickling filter	0.942	Mississippi River

2. Known industrial - None

† See "Report on Wolf Lake", Working Paper No. 136.
†† See "Report on Lake Andrusia", Working Paper No. 81.
* 1970 Census.
** Estimated at 100 gal/capita/day.
*** Indirect.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Mississippi River	17,800	36.3
Pike Bay outlet	1,050	2.2
Kitchi Lake outlet	7,010	14.3
b. Minor tributaries & immediate drainage (non-point load) -	950	1.9
c. Known municipal -		
Cass Lake	3,290	6.7
Bemidji (indirect)	16,480	33.6
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	2,430	5.0
Total	49,010	100.0

2. Outputs -

Lake outlet - Mississippi River 17,900

3. Net annual P accumulation - 31,110 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Mississippi River	611,010	50.2
Pike Bay outlet	47,170	3.9
Kitchi Lake outlet	270,320	22.2
b. Minor tributaries & immediate drainage (non-point load) -	36,910	3.0
c. Known municipal -		
Cass Lake	9,880	0.8
Bemidji (indirect)	92,410	7.6
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	150,250	12.3
Total	1,217,950	100.0

2. Outputs -

Lake outlet - Mississippi River 994,010

3. Net annual N accumulation - 223,940 pounds

* See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
Mississippi River	24	835
Pike Bay outlet	28	1,251
Kitchi Lake outlet	23	895

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving water would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	3.1	2.0	78.1	14.4
grams/m^2/yr	0.35	0.22	8.8	1.6

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Cass Lake:

"Dangerous" (eutrophic rate)	0.58
"Permissible" (oligotrophic rate)	0.29

V. LITERATURE REVIEWED

Anonymous, 1973. Wastewater disposal facilities inventory. MPCA, Minneapolis.

Bonnema, Kenneth, and William G. Johnson, 1972. Control of aquatic vegetation, algae, leeches and swimmer's itch in 1971. Dept. Nat. Resources, St. Paul.

Lang, D. E., J. F. McGuire, and K. M. Bishop; 1969. Report on investigation of water quality of Wolf, Andrusia and Cass lakes. MPCA, Minneapolis.

Schilling, Joel, 1974. Personal communication (lake map; treatment requirements at Bemidji). MPCA, Minneapolis.

Vollenweider, Richard A., (in press). Input-output models. Schweiz. A. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2715 CASS LAKE

TOTAL DRAINAGE AREA OF LAKE 1130.00

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2715A1	1130.00	321.30	285.40	330.30	1323.20	1595.60	1174.50	628.60	374.20	438.10	452.00	284.40	30 40	626.50
2715C1	37.70	5.74	4.14	7.45	40.40	55.60	43.60	21.90	11.20	18.80	14.60	7.60	8.16	20.01
2715D1	732.00	261.00	204.00	246.00	837.00	1054.00	788.00	417.00	240.00	313.00	295.00	181.00	212.00	421.25
2715F1	302.00	69.10	59.20	70.90	360.60	474.00	351.00	168.00	85.20	105.00	132.00	77.00	66.00	168.58
2715Z7	54.20	2.14	1.55	4.79	46.40	47.40	51.40	18.80	6.03	12.90	7.55	3.75	3.56	17.25

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1130.00
SUM OF SUB-DRAINAGE AREAS = 1125.90

TOTAL FLOW IN = 7513.87
TOTAL FLOW OUT = 7507.99

NOTE *** TRIB 1501=C0C1

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2715A1	10	72	415.00	14	548.00				
	11	72	352.00	5	352.00				
	12	72	453.00	10	439.00				
	1	73	365.00	20	318.00				
	2	73	306.00	18	306.00				
	3	73	907.00	17	2730.00				
	4	73	191.00	1	202.00	14	176.00		
	5	73	207.00	19	168.00				
	6	73	248.00						
	7	73	300.00	8	247.00				
	8	73	133.00	11	133.00				
	9	73	460.00	16	534.00				
2715C1	10	72	13.40	14	18.00				
	11	72	9.34	5	9.40				
	12	72	12.30	10	12.00				
	1	73	6.31	20	5.50				
	2	73	4.43	18	4.40				
	3	73	21.40	17	64.00				
	4	73	15.50	1	16.00	14	14.00		
	5	73	15.00	19	14.00				
	6	73	12.60						
	7	73	10.00	8	8.90				
	8	73	8.73	11	8.70				
	9	73	15.00	16	17.00				

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2715 CASS LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2715D1	10	72	270.00	14	356.00				
	11	72	223.00	5	223.00				
	12	72	319.00	10	309.00				
	1	73	287.00	20	250.00				
	2	73	218.00	18	218.00				
	3	73	672.00	17	2020.00				
	4	73	270.00	1	286.00	14	248.00		
	5	73	264.00	19	240.00				
	6	73	230.00						
	7	73	205.00	8	182.00				
	8	73	200.00	11	200.00				
	9	73	300.00	16	348.00				
2715E1	10	72	121.00	14	160.00				
	11	72	95.00	5	95.00				
	12	72	102.00	10	99.00				
	1	73	76.00	20	66.00				
	2	73	63.30	18	63.00				
	3	73	194.00	17	584.00				
	4	73	123.00	1	130.00	14	113.00		
	5	73	120.00	19	109.00				
	6	73	98.80						
	7	73	80.00	8	71.00				
	8	73	70.00	11	70.00				
	9	73	120.00	16	139.00				
2715Z2	10	72	6.92	14	9.10				
	11	72	4.63	5	4.60				
	12	72	5.36	10	5.20				
	1	73	2.62	20	2.30				
	2	73	1.66	18	1.70				
	3	73	13.10	17	39.00				
	4	73	22.30	1	24.00	14	21.00		
	5	73	21.70	19	20.00				
	6	73	18.00						
	7	73	14.00	8	13.00				
	8	73	13.00	11	13.00				
	9	73	22.00	16	25.00				

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

271501
47 24 45.0 094 37 40.0
CASS LAKE
27 MINNESOTA

11EPALES 2111202
4 0044 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/11	18 30	0000			42							
	18 30	0004	23.0	10.1		280	8.40	138	0.060	0.070	0.020	0.008
	18 30	0015	20.4	5.6		290	8.20	150	0.070	0.080	0.016	0.009
	18 30	0020	8.6	5.4		300	7.70	156	0.050	0.070	0.018	0.013
	18 30	0030	12.4	0.2		330	7.30	172	0.050	0.230	0.024	0.015
	18 30	0041	8.1	0.6		340	7.20	175	0.080	0.580	0.120	0.025
72/09/07	15 00	0000			68	248	8.25	133	0.050	0.150	0.026	0.010
	15 00	0004	17.8	5.9		248	8.25	132	0.040	0.150	0.026	0.010
	15 00	0010	17.8	7.4		248	8.25	136	0.060	0.150	0.020	0.009
	15 00	0015	17.7	6.6		250	8.25	136	0.060	0.150	0.020	0.008
	15 00	0020	17.7	6.8		248	8.25	137	0.060	0.150	0.023	0.009
	15 00	0025	17.7	5.3		250	8.20	140	0.060	0.160	0.020	0.009
	15 00	0030	17.3	4.1		250	8.20	140	0.050	0.280	0.024	0.010
	15 00	0035	13.7	0.1		295	7.40	169	0.050	0.880	0.083	0.029
	15 00	0040	10.7	0.04		310	7.35	173	0.090	1.290	0.168	0.025
72/10/21	11 00	0000			58	294	8.40	136	0.020	0.030	0.025	0.010
	11 00	0004	5.4	9.8		280	8.40	135	0.020	0.030	0.031	0.016
	11 00	0015	5.8	9.8		280	8.40	136	0.020	0.040	0.027	0.015
	11 00	0020	5.8	10.8		280	8.40	139	0.020	0.040	0.025	0.012
	11 00	0025	5.8	10.8		280	8.40	140	0.030	0.040	0.023	0.011
	11 00	0035	5.8	10.8		290	8.40	141	0.050	0.060	0.027	0.011
	11 00	0035	5.6	11.0		290	8.30	140	0.020	0.060	0.023	0.015
	11 00	0040	5.5	10.9		296	8.30	141	0.020	0.060	0.028	0.013

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/11	18 30	0000	13.1J
72/09/07	15 00	0000	6.5J
72/10/21	11 00	0000	14.4J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 74/10/30

271502
47 23 30.0 094 35 06.0
CASS LAKE
27 MINNESOTA

11EPALES
4

2111202
0019 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/11	19	15 0000			66							
	19	15 0004	21.7	10.6		290	8.30	140	0.060	0.080	0.012	0.005
72/09/07	10	20 0000			87	250	8.30	143	0.070	0.140	0.016	0.008
	10	20 0004	17.4	7.6		250	8.30	138	0.060	0.120	0.016	0.008
	10	20 0015	16.9	7.2		250	8.30	141	0.060	0.120	0.014	0.008
72/10/21	09	45 0000			48	298	8.20	140	0.040	0.060	0.020	0.009
	09	45 0004	5.2	11.0		290	8.20	140	0.050	0.070	0.019	0.014

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/11	19	15 0000	7.0J
72/09/07	10	20 0000	5.0J
72/10/21	09	45 0000	15.9J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 74/10/30

271503
47 26 50.0 094 31 00.0
CASS LAKE
27 MINNESOTA

11EPALES
4

2111202
0022 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/11	19	30 0000			72							
	19	30 0004	23.9	8.8		290	8.20	144	0.040	0.050	0.010	0.006
	19	30 0015	20.9	9.2		300	8.20	143	0.040	0.050	0.011	0.005
	19	30 0021	19.4	8.4		30	8.10	146	0.040	0.050	0.010	0.006
72/09/07	09	45 0000			123	258	8.50	142	0.060	0.090	0.013	0.007
	09	45 0004	17.8	7.4		258	8.50	141	0.060	0.080	0.011	0.006
	09	45 0015	17.4	8.3		260	8.45	139	0.060	0.080	0.011	0.006
	09	45 0018	17.3	8.3		260	8.50	140	0.060	0.080	0.011	0.007
72/10/21	10	25 0000			102	285	8.30	138	0.010	0.050	0.014	0.006
	10	25 0004	6.6	10.9		280	8.30	140	0.030	0.040	0.012	0.007
	10	25 0015	6.6	10.6		280	8.30	142	0.040	0.050	0.016	0.009
	10	25 0018	6.6	10.4		290	8.20	140	0.030	0.040	0.017	0.009

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/11	19	30 0000	3.2J
72/09/07	09	45 0000	4.6J
72/10/21	10	25 0000	6.4

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 74/10/30

2715A1 LS2715A1
47 27 00.0 094 28 30.0
MISSISSIPPI RIVER
27 CO #4, SHEET #1
0/CASS LAKE
CO HWY 39 BRDG .5 MI DOWNSTREAM OF LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	11 30		0.040	0.550	0.063	0.005K	0.018
72/11/05	12 27		0.010K	0.400	0.020	0.005K	0.016
73/01/20	11 40		0.020	0.440	0.044	0.015	
73/02/18	14 00		0.035	0.520	0.065	0.013	0.013
73/03/17	10 47		0.072	0.910	0.028	0.005K	0.010
73/04/01	15 30		0.040	1.260	0.019	0.005K	0.015
73/04/14	10 45		0.024	0.460	0.007	0.005K	0.015
73/05/19	11 40		0.010K	0.480	0.005K	0.005K	0.015
73/06/03	11 40		0.010K	1.050	0.010	0.005K	0.020
73/07/08	12 05		0.010K	2.400	0.015	0.005K	0.010
73/08/11	10 35		0.210	0.520	0.014		0.030
73/09/16	11 15		0.010K	0.750	0.020	0.005K	0.015

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/[illegible]/30

2715A2 LS2715A2
47 30 00.0 094 48 00.0
MISSISSIPPI RIVER
27 7.5 BEMIDJI EAST
T/CASS LAKE
LT QTY RD 4RDG 1.5 MI E OF BEMIDJI LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/11/05	10 45		0.070	0.660	0.138	0.110	0.130
72/12/10	10 30		0.054	0.900	0.230	0.092	0.110
73/01/20	09 50		0.132	0.920	0.189	0.099	0.110
73/03/17	09 02		0.069	0.960	0.039	0.014	0.025
73/04/01	13 50		0.027	0.690	0.007	0.005K	0.020
73/04/14	09 15		0.010K	1.540	0.048	0.066	0.155
73/04/19	12 55		0.740	2.600	0.074	0.005K	0.015
73/05/19	09 55		0.010K	1.100	0.005K	0.058	0.130
73/06/03	09 55		0.014	2.200	0.054	0.132	0.280
73/07/08	09 55		0.017	0.920	0.058	0.062	0.115
73/08/11	08 30		0.210	0.880	0.090	0.110	0.130
73/09/16	09 45		0.050	0.640	0.044	0.028	0.050

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

2715A3 LS2715A3
47 29 00.0 094 43 30.0
MISSISSIPPI RIVER
27 CO #4, SHEET #1
T/CASS LAKE
CO HWY 12 BRDG HELO HEMIDJI STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	12 00		0.017	0.575	0.044	0.044	0.080
72/11/05	10 55		0.017	0.540	0.025	0.061	0.105
72/12/10	10 45		0.082	0.690	0.154	0.088	0.115
73/01/20	10 10		0.096	0.630	0.170	0.092	0.100
73/02/18	12 30		0.140	0.780	0.190	0.110	0.130
73/03/17	09 15		0.126	2.200	0.198	0.072	0.095
73/04/01	14 00		0.042	0.600	0.005K	0.006	0.047
73/04/14	09 25		0.010K	0.580	0.005K	0.007	0.055
73/05/19	10 05		0.010K	0.560	0.005K	0.021	0.050
73/06/03	10 00		0.010K	0.720	0.017	0.038	0.075
73/07/08	10 05		0.010K	0.580	0.007	0.034	0.075
73/08/11	08 40		0.010K	0.630	0.023	0.056	0.085
73/09/16	09 55		0.050	0.920	0.115	0.044	0.070

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

271581 LS271581
47 22 30.0 094 36 30.0
UNNAMED TRIB TO PIKE BAY
27 CO #11, SHEET #4
T/CASS LAKE
CO HWY 146 BRDG ABOVE CASS LAKE STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14			0.700	0.275	0.075	0.009	0.027
72/11/05	12 00		0.850	0.270	0.044	0.009	0.016
73/01/20	11 20		0.870	0.370	0.160	0.015	0.020
73/03/17	10 15		0.740	0.720	0.189	0.015	0.035
73/04/01	15 00		0.600	0.890	0.023	0.005K	0.005K
73/04/14	10 25		0.740	0.300	0.015	0.006	0.020
73/05/19	11 14		0.280	0.490	0.021	0.012	0.065
73/06/03	11 15		0.300	0.530	0.044	0.014	0.040
73/07/08	11 45		0.189	0.580	0.088	0.006	0.030
73/08/11	09 10		0.480	0.840	0.054	0.017	0.030
73/09/16	10 45		0.600	0.400	0.056	0.010	0.020

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

2715C1 LS2715C1
47 23 00.0 094 35 30.0
CASS LK/PIKE BAY NARROWS
27 CO #11. SHEET #4
T/CASS LAKE
US 2 BRDG BELO CASS LAKE STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	12 30		0.024	0.500	0.052	0.005K	0.036
72/11/05	12 07		0.015	0.460	0.039	0.005K	0.025
73/03/17	10 25		0.084	0.560	0.069	0.007	0.017
73/04/01	15 10		0.018	1.100	0.039	0.005K	0.020
73/04/14	10 30		0.010K	1.300	0.005K	0.005K	0.025
73/05/19	11 25		0.010K	0.540	0.005K	0.005K	0.030
73/06/03	11 20		0.010K	0.720	0.016	0.006	0.035
73/07/08	11 55		0.010K	1.600	0.021	0.005K	0.015
73/08/11	10 15			0.960	0.015	0.007	0.025
73/09/18	11 00		0.027	0.630	0.015	0.005K	0.015

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

2715E1 LS2715E1
47 29 00.0 094 31 30.0
KITCHI LK/CASS LK CONNECTION
27 CO #4, SHEET #1
T/CASS LAKE
CO HWY 12 BRDG 2 MI W OF PENNINGTON
11EPALFS 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14			0.022	0.825	0.042	0.005K	0.033
72/11/05	12 30		0.019	0.670	0.042	0.007	0.025
72/12/10	12 20		0.021	0.720	0.044	0.006	0.018
73/01/20	11 45		0.094	0.710	0.037	0.010	0.015
73/02/19	14 20		0.168	0.690	0.028	0.011	0.015
73/03/17	10 55		0.200	0.800	0.026	0.005K	0.015
73/04/01	15 40		0.147	0.790	0.008	0.005K	0.015
73/04/14	10 56		0.038	0.780	0.014	0.005K	0.025
73/05/19	11 55		0.010K	1.100	0.046	0.046	0.085
73/06/03	11 55		0.010K	0.720	0.025	0.006	0.025
73/07/08	12 15		0.010K	0.840	0.009	0.005K	0.025
73/08/11	10 40		0.058	0.840	0.046	0.007	0.030
73/09/16	11 30		0.010K	0.830	0.021	0.007	0.035

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

271551 IP271551 P001317
47 22 30.0 094 35 30.0
CASS LAKE
27 CO #11 SHEET #4
T/CASS LAKE
CASS LAKE/PIKE BAY NARROWS
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/17	13 00		0.810	33.500	11.800	4.600	7.200	1.000	
73/02/07			0.115	41.000	20.000	8.800	13.500		
73/03/07			0.165	35.700	15.800	7.300	10.500		
73/04/04			0.020	47.000	24.000	9.900	13.000		
73/05/22			0.070	47.000		15.600	22.000		
73/06/26			0.130	39.600	23.200	10.800	13.500		
73/08/29	10 00			43.100	20.300	10.200	15.000	0.024	0.025
73/10/09	09 00		0.070	27.000	24.000	7.600	8.900	0.024	
73/10/16	13 30		0.040	49.000	30.000	10.400	14.000		0.024
73/11/14	11 00		0.110	37.500	17.000	6.150	9.600		0.024
73/12/12	10 00		0.180	40.000	23.000	8.500	12.000		
74/01/21	10 00		0.760	46.000	22.000	9.900	13.000		

b2

STORET RETRIEVAL DATE 74/11/14

27C0C1 271501
47 26 30.0 094 38 30.0
LK ANDRUSIA/CASS LAKE CONNECTION
27 CO #4, SHEET #1
0/LAKE ANDRUSIA
CO HWY 33 BRDG 3.5 MI NW OF CASS LAKE
11FPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	12	30	0.110	1.050	0.088	0.010	0.069
72/11/05	11	10	0.045	0.720	0.052	0.024	0.031
72/12/10	11	13	0.022	0.630	0.054	0.018	0.033
73/01/20	10	40	0.065	0.610	0.126	0.039	0.050
73/02/18	12	50	0.091	0.670	0.115	0.042	0.065
73/03/17	09	37	0.176	0.630	0.074	0.034	0.055
73/04/01	14	15	0.120	0.690	0.016	0.008	0.055
73/04/14	09	45	0.014	2.000	0.058	0.007	0.050
73/05/19	10	30	0.010K	0.600	0.005K	0.005K	0.035
73/06/03	10	25	0.010K	0.580	0.009	0.005K	0.030
73/07/09	10	30	0.010K	0.940	0.012	0.007	0.030
73/09/11	09	00	0.010K	1.080	0.019	0.009	0.050
73/09/16	10	15	0.010K	1.100	0.024	0.014	0.070

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/11/14

274251 TF274251 P011490
47 29 30.0 094 50 00.0
6E41DJI
27 CO #4 SHEET #1
T/#OLF LAKE
MISSISSIPPI RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 N02&N03 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/29	11 00								
CP(T)-			1.250	39.900	22.000	5.400	8.400	0.785	0.984
73/01/29	13 00								
73/02/28	10 30								
CP(T)-			1.260	41.000	24.000	8.200	9.000	1.000	0.900
73/02/28	12 30								
73/03/30	10 30								
CP(T)-			2.300	28.000	11.600	9.200	9.600	0.900	0.866
73/03/30	13 00								
73/04/30	11 00								
CP(T)-			2.100	30.000	13.200	6.200	10.300	1.000	0.846
73/04/30	13 00								
73/05/31	11 00								
CP(T)-			2.820	42.000	25.100	8.890	11.500	1.350	1.000
73/05/31	13 00								
73/06/29	11 00								
CP(T)-			2.200	31.000	14.400	6.600	9.900	1.200	1.200
73/06/29	13 00								
73/07/31	11 00								
CP(T)-			2.800	26.000	7.000	3.300	9.680	1.000	1.000
73/07/31	13 00								
73/09/04	10 30								
CP(T)-			2.040	28.600	8.100			1.200	1.000
73/09/04	12 30								
73/10/01	11 00								
CP(T)-			1.050	31.500	20.000	7.000	10.500	0.925	0.900
73/10/01	13 00								
73/10/31	12 00								
CP(T)-			0.540	40.000	14.000	6.000	12.000	0.950	0.900
73/10/31	14 00								
73/11/30	11 00								
CP(T)-			0.060	49.000	28.000	4.900	11.000	0.870	0.790
73/11/30	13 00								
74/01/02	11 00								
CP(T)-			2.000	31.500	21.000	10.600	11.500	0.900	0.977
74/01/02	13 00								

STORET RETRIEVAL DATE 74/11/14

27A251 TF27A251 P011490
47 29 30.0 094 50 00.0
HEMIDJI
27 CO #4 SHEET #1
T/WOLF LAKE
MISSISSIPPI RIVER
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/02/04 CP(T)- 74/02/04	10 00 12 00		2.320	17.600	17.600	9.600	12.500	0.950	0.932